3.2 Chemicals in the Landscape

This section focuses on the extent, potential disposition, and effects of chemicals used or managed on land. The production and use of chemicals in the U.S. has increased over the last 50 years. The use and release of chemicals can have various effects on human health and ecological condition. Commercial and industrial processes such as mining, manufacturing, and the generation of electricity all use and release chemicals. Chemicals that control weeds, insects, rodents, fungi, bacteria, and other organisms are called pesticides and are commonly used on agricultural lands, as well as in urban, industrial, and residential settings. Fertilizers—supplements to improve plant growth—are also used extensively in a variety of settings. Pesticides and fertilizers have contributed to high agricultural productivity levels in the U.S.

EPA began monitoring the production and importation of industrial chemicals in 1977 through the Toxics Substances Control Act Chemical Inventory, which presently identifies more than 76,000 chemicals used in U.S. commerce. Nearly 10,000 of these chemicals are produced or imported in quantities greater than 10,000 pounds per year (excluding inorganics, polymers, microorganisms, naturally occurring substances, and non-isolated intermediaries). About 3,100 of these chemicals are produced or imported in quantities exceeding 1 million pounds per year. Associated annual production/import volumes increased by 570 billion pounds (9.3 percent) to 6.7 trillion pounds between 1990 and 1998 (EPA, OPPTS, 2002).

The questions posed in this section consider the amounts and types of chemicals released to the landscape, addressing toxic substances, pesticides, and fertilizers. The discussion also looks at the potential for chemicals to move from their use on land to places where humans and other organisms can be exposed to them. In this context, questions also address what is currently known about health and ecological effects from exposure to chemicals used on land.

The six questions considered in this section are:

- How much and what types of toxic substances are released into the environment?
- What is the volume, distribution, and extent of pesticide use?
- What is the volume, distribution, and extent of fertilizer use?
- What is the potential disposition of chemicals from land?
- What human health effects are associated with pesticides, fertilizers, and toxic substances?
- What ecological effects are associated with pesticides, fertilizers, and toxic substances?

The primary sources of data for this section are the EPA Toxics Release Inventory (TRI), describing quantities of toxic chemical releases; pesticide use estimates (based on sales) from both EPA and the non-profit National Center for Food and Agricultural Policy (NCFAP); data from the USDA's *Agricultural Resources and Environmental Indicators* report published in 2000 on the volume, distribution, and extent of fertilizer use (see Appendix B); and data from the USDA Pesticide Data Program on pesticide residues found on food samples.

3.2.1 How much and what types of toxic substances are released into the environment?

Indicator

Quantity and type of toxic chemicals released and managed

Many industries release toxic substances into the air, soil, and water through their manufacturing and production activities. Under the Emergency Planning and Community Right-to-Know Act of 1986 and the Pollution Prevention Act of 1990, most facilities are required to calculate and report to EPA and states their release and other waste management quantities of more than 650 toxic chemicals and chemical categories. Intended uses of this information include helping communities prepare for chemical spills and similar emergencies and educating the public on industries' release and other waste management practices for toxic chemicals. EPA makes these toxic release data available to the public annually via the *Toxics Release Inventory* (TRI) *Public Data Release Report*.

The indicator identified for this question addresses quantity and type of toxic chemicals released and managed as waste as well as trends.

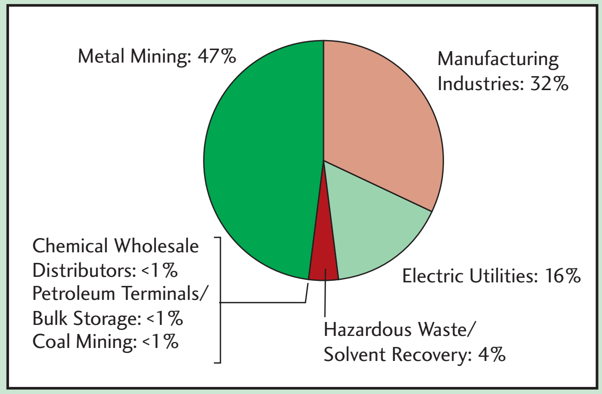
Indicator

Quantity and type of toxic chemicals released and managed - Category 2

The data collected in TRI represent only part of a broader universe of chemicals used and released into the environment. TRI includes a large amount of information on a range of categories of toxic chemicals, including many arsenic, cyanide, dioxin, lead, mercury, and nitrate compounds and provides information on the amount and trends in releases and management of chemicals, including recycling, recovery, and treatment. TRI data cover releases from reporting facilities in all parts of the country and can be searched for releases within individual zip codes. All data presented below can be found in the *EPA 2000 Toxics Release Inventory Public Data Release Report* (EPA, OEI, May 2002).

Exhibit 3-13: Total toxic release inventory (TRI) releases by industry, 2000

(Total = 7 billion pounds)



Source: EPA, Office of Environmental Information. *2000 Toxics Release Inventory (TRI) Public Data Release Report.* May 2002.

What the Data Show

Releases to the environment for all EPA-tracked TRI chemicals from nearly 23,500 facilities totaled 7 billion pounds in 2000. Of these releases, 58 percent were to land, 27 percent were to air, 4 percent each were to water and underground injection at the generating facility, and 7 percent were chemicals disposed of off-site to land or underground injection. Three industries accounted for most of the releases: metal mining (27 facilities) accounted for 47 percent, manufacturing industries (21,352 facilities) for 32 percent, and electric utilities (706 facilities) for 16 percent. The remaining 5 percent was split among hazardous waste/solvent recovery, coal mining, petroleum terminals/bulk storage, and chemical wholesale distributors (Exhibit 3- 13).

Exhibit 3-14: Toxics release inventory (TRI) total releases and change by industry, 1998-2000

Source: EPA, Office of Environmental Information. *2000 Toxics Release Inventory (TRI) Public Data Release Report.* May 2002.

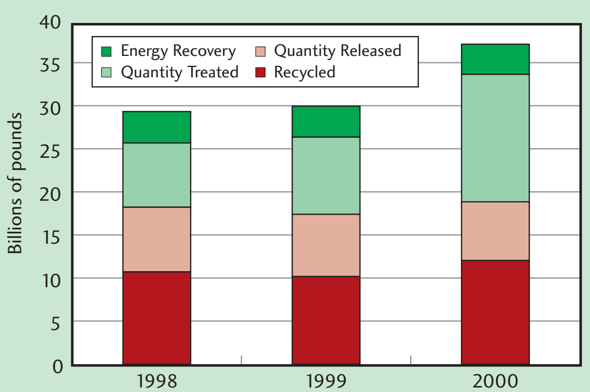
Between 1998 and 2000, the total amount of toxic releases as estimated by the TRI decreased by approximately 409 million pounds, or 5.5 percent. Of that total, releases to land decreased approximately 276 million pounds. Decreases in the releases by certain industries (e.g., manufacturing and metal mining) account for most of the overall decrease between 1998 and 2000. A few industries (e.g., hazardous waste/solvent recovery, coal mining, and chemical wholesale distributors) increased their releases during this time period. Off-site releases from production increased by 75 million pounds in the 1998 to 2000 time frame (Exhibit 3-14).

Indicator Quantity and type of toxic chemicals released and managed - Category 2 (continued)

The seven billion pounds of chemicals actually released into the environment (air, water, and land) are a subset of toxic chemicals managed and tracked in TRI. Another 31 billion pounds of toxic chemicals were managed as waste in 2000. Nearly all (>99 percent) of these toxic chemicals were production related, Of the 31 billion pounds, 50 percent was treated, 39 percent was recycled, and 11 percent was burned for energy recovery.

The total amount of toxic chemicals managed as waste during the three-year period of 1998 to 2000 increased by almost 29 percent, a net increase of 8.4 billion pounds (Exhibit 3-15). Two industries in the southeastern U.S., printing/publishing and chemicals and allied products, accounted for most of this increase. Between 1998 and 2000, the chemicals recycled increased by more than 12 percent (1.3 billion pounds). In contrast, the quantities of chemicals combusted for energy recovery decreased 4.1 percent.

Exhibit 3-15: Trends in toxic chemicals 1998-2000



Note: The data shown as "Quantity Released" vary from the data in Exhibit 3-14 because some facilities include off-site transfers for disposal to other TRI facilities that then report the amount as on-site release.

Source: EPA, Office of Environmental Information. *2000 Toxics Release Inventory (TRI) Public Data Release Report.* May 2002.

The TRI data are also used to support EPA's National Waste Minimization Partnership Program, which focuses on reducing or eliminating the generation of hazardous waste containing any of 30 Waste Minimization Priority Chemicals (WMPC). These chemicals are found in hazardous waste and are documented contaminants of air, land, water, plants and animals. EPA has tracked 17 of these chemicals since 1991 and reports that WMPC generation quantities have been steadily declining since 1993 (Exhibit 3-16). Overall, between 1991 and 1998, the generation of WMPC in industrial hazardous and solid waste decreased by 44 percent.

Indicator Gaps and Limitations

The TRI data do not reflect a comprehensive total of toxic releases nationwide. Although EPA has added to the number of industries (SIC codes) that must report, the TRI program does not cover all releases of chemicals from all industries. Second, industries are not required to report the release of several types of toxic chemicals, because these chemicals are not included in the TRI list. Third, facilities that do not meet the TRI reporting requirements (those with fewer than 10 full-time employees or the

Waste Minimization Priority Chemicals

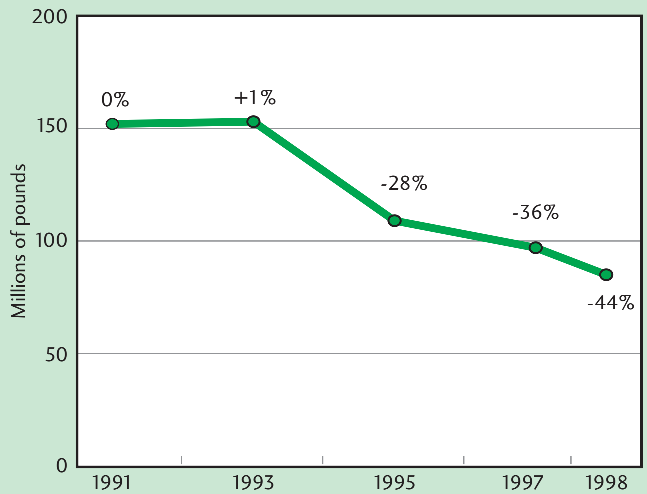
Organic chemicals and chemical compounds:
*1,2,4-Trichlorobenzene
1,2,4,5-Tetrachlorobenzene
*2,4,5-Trichlorophenol
4-Bromophenyl phenyl ether
Acenaphthene
Acenaphthylene
*Anthracene
Benzo(g,h,i)perylene
*Dibenzofuran
Dioxins/Furans (considered one chemical on this list)
Endosulfan, alpha & Endosulfan, beta (considered one chemical on this list)
Fluorene
*Heptachlor & Heptachlor epoxide (considered one chemical on this list)
*Hexachlorobenzene
*Hexachlorobutadiene
*Hexachlorocyclohexane, gamma-
*Hexachloroethane
*Methoxychlor
*Naphthalene
PAH Group (as defined in TRI)
Pendimethalin
Pentachlorobenzene
*Pentachloronitrobenzene
*Pentachlorophenol
Phenanthrene
Pyrene
*Trifluralin

Metal and Metal Compounds:
*Cadmium
*Lead
*Mercury

(*17 chemicals tracked since 1991)

Indicator Quantity and type of toxic chemicals released and managed - Category 2 (continued)

Exhibit 3-16: Trends in toxics release inventory (TRI) Waste Minimization Priority Chemicals (WMPC), 1991-1998



Source: EPA, Office of Solid Waste and Emergency Response. *Waste Minimization Trends Report (1991-1998)*. September 2002.

employee equivalent, or those not meeting TRI chemical-specific reporting threshold amounts) are not required to report their releases and therefore are not included as part of the total. Finally, facilities report their release and other waste management data to TRI using monitoring data, emission factors, mass balance approaches and engineering calculations. EPA does not mandate monitoring of releases, although many industries do conduct monitoring. Various estimation techniques are used when monitoring data are not available. EPA has published estimation guidance for the regulated community, but not all industrial facilities use consistent estimation methodologies, and variations in reporting may result. With approximately 76,000 different types of chemicals in existence, and new ones constantly being developed, the challenge is to ensure that those that are likely to pose the greatest hazards are tracked and managed.

Data Source

The data source for this indicator is EPA, Toxics Release Inventory, 2000. (See Appendix B, page B-20, for more information.)

3.2.2 What is the volume, distribution, and extent of pesticide use?

Indicator
Agricultural pesticide Use

Pesticides are substances or mixtures of substances intended for preventing, destroying, repelling, or mitigating plant or animal pests. Conventional pesticides include herbicides, plant growth regulators, insecticides, fungicides, nematicides, fumigants, rodenticides, molluscicides, aquatic pesticides, and fish/bird pesticides. Most pesticides create some risk of harm to humans, animals, or the environment because they are designed to kill or otherwise adversely affect living organisms. At the same time, pesticides are useful to society because of their ability to kill potential disease-causing organisms and control insects, weeds, and other pests.

Currently, no reporting system provides information on the volume, distribution, and extent of pesticide use nationwide across all sectors. Estimates, however, of total pesticide use have been developed based on available information such as crop profiles, pesticide sales, and expert surveys. Several of these data sets are collected by the private or non-profit sectors rather than federal agencies.

EPA's recent *Pesticide Industry Sales and Usage Report* estimates show that conventional annual pesticide use declined by about 15 percent between 1980 and 1999. This change has not been steady; in 1999, pesticide use was higher than it was in the early 1990s. Of the three sectors of pesticide use assessed in EPA estimates (agricultural, industry-commercial-government, and home-garden), the industrial-commercial-government use of pesticides has seen the most steady decline over this 20-year period. EPA estimates show that in 1999, agricultural pesticide use accounted for nearly 77 percent (956 million pounds) of all pesticide use; home and garden use was 11 percent (140 million pounds); and industrial, commercial, and government use was nearly 12 percent (148 million pounds) of total conventional pesticide use (1244 million pounds). These estimates do not include wood preservatives, biocides, and chlorine/hypochlorites (EPA, OPPTS, 2002).

An important class of pesticides—insecticides—has undergone significant use reduction in the last 5 years. Insecticides, as a class, tend to be the most acutely toxic pesticides to humans and wildlife. The number of individual chemical treatments per acre, referred to as "acre-treatments," for insecticides labeled "danger for humans" has undergone a 43 percent reduction in use from 1997 to 2001. Over the same period, acre-treatments for insecticides labeled "extremely or highly toxic to birds" have been reduced by 50 percent, and insecticides labeled "extremely or highly toxic to aquatic organisms" have been reduced by 23 percent (EPA, OPP, 2001). The indicator identified for this question specifically addresses agricultural pesticide use.

Indicator Agricultural pesticide use - Category 2

Building on EPA and USDA estimates, as well as on pesticide use surveys, the National Center for Food and Agricultural Policy (NCFAP), a private, non-profit, research organization, has established a pesticide use database that provides estimates of agricultural pesticide use by chemical, crop, and state.

What the Data Show

According to NCFAP, and as shown in Exhibit 3-17, total agricultural pesticide use increased from 892 to 985 million pounds between 1992 and 1997. (EPA reports a similar increase in use of all pesticides in this same time frame, and a leveling of use between 1997 and 1999.) (EPA, OPPTS, 2002). Approximately half of these agricultural pesticides are herbicides used to control weeds that limit or inhibit the growth of the desired crop. While many pesticides are synthetic chemicals, some biopesticides, such as *Bacillus thuringiensis,* are also broadly used and are key components of organic farming programs.

The 1997 NCFAP summary report shows that more pesticides are used on corn than on any other crop. At the same time, corn is planted on more acres than any other single crop. It is also most effectively treated with a combination of chemicals that are applied in high quantities per acre.

Oil, most often applied as a spray, is used in greater quantities than any other pesticide across all crops. In the context of the NCFAP report, "oil" includes plant oil extracts with insecticidal properties, vegetable oils that work by smothering pests, and petroleum derivatives used as solvents and insecticides. Sulfur—through its broad applicability as an insecticide, fungicide, and rodenticide—and atrazine, largely due to its use with corn, are the next two most commonly used chemicals.

Indicator Gaps and Limitations

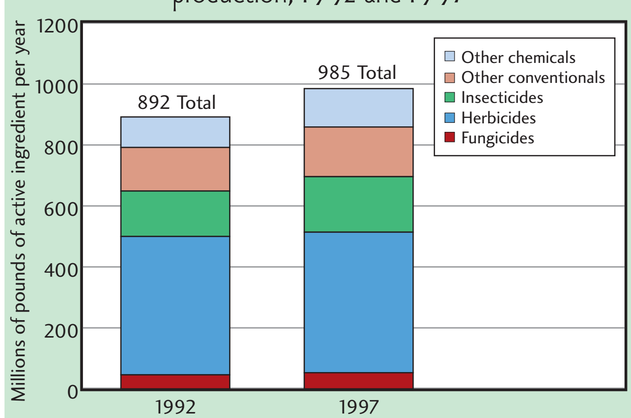
Limitations for this indicator include the following:

- The data quality of the NCFAP national pesticide use database is unknown. The database is not a direct record based on reports of actual usage and application. Some of the database estimates are derived from surveys of farmers, and others are expert opinions from knowledgeable extension service specialists. Also, because of the absence of data for many states and crops, many records have been assigned based on the data from a nearby state. It is unclear how accurate these sources and procedures are. The 1997 summary report for the database carefully makes no claims to statistical accuracy because of the variety of sources and techniques for estimation of chemical usage. Several federal agencies, however, use the information, and NCFAP has received funding from USDA to update the pesticide use database for 2002 (Gianessi and Marcelli, 2000).
- NCFAP data only report on the agricultural use of pesticides, which leaves out other commercial non-agricultural and residential applications. Additional data would be advantageous for tracking these uses of pesticides.

Data Source

The data source for this indicator is the National Center for Food and Agricultural Policy's Pesticide Use Database, 2000. (See Appendix B, page B-21, for more information.)

Exhibit 3-17: Pesticide use in crop production, 1992 and 1997



Source: Gianessi, L.P., and M.B. Marcelli. *Pesticide Use in U.S. Crop Production: 1997, National Summary Report.* November 2000.

3.2.3 What is the volume, distribution, and extent of fertilizer use?

Indicator
Fertilizer use

Fertilizers have contributed to an increase in commercial agricultural productivity in the U.S. throughout the latter half of the 20th century. Using fertilizers and soil amendments, farmers have successfully enhanced the productivity of marginal soils and shortened recovery times for damaged areas. Similar to pesticide use, however, the increasing use of commercial fertilizers in agriculture has consequences for human health and ecological condition. Between World War II and the early 1980s, commercial fertilizer use increased consistently and significantly (Battaglin and Goolsby, 1994). Fertilizer use patterns today are greatly influenced by crop patterns, economic and climatic factors, and crop reduction programs implemented by local and federal government agencies (Council on Environmental Quality, 1993). The indicator identified for this question specifically addresses the volume, distribution, and extent of fertilizer use.

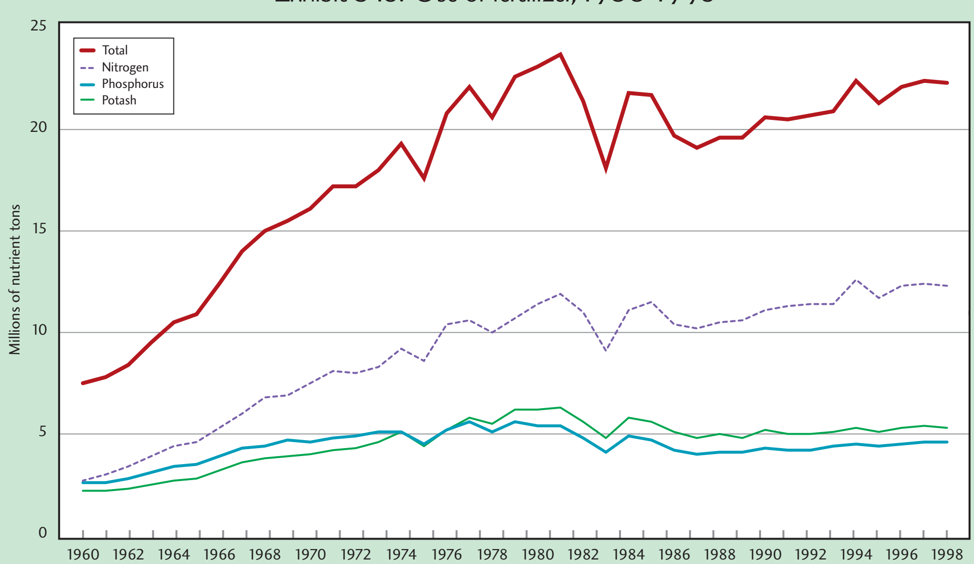
Indicator | Fertilizer use - Category 2

Most data on the volume and distribution of fertilizer use are based on sales data collected by USDA. Usage is concentrated heavily in the midwestern states where agricultural production—particularly that of corn—is greatest.

What the Data Show

According to the *2000 USDA Agricultural Resources and Environmental Indicators Report,* the use of nitrogen, phosphorus, and potash—the most prevalent supplements used in fertilizers for commercial farming—rose from 7.5 million nutrient tons in 1961 to 23.7 million tons in 1981. Although aggregate use dipped in 1983, it increased most recently between 1996 and 1998 to more than 22 million nutrient tons (Daberkow, et al, 2003) (Exhibit 3-18).

Exhibit 3-18: Use of fertilizer, 1960-1998



Source: Daberkow, et al. *Agricultural Resources and Environmental Indicators: Nutrient Use and Management.* February 2003.

Indicator Gaps and Limitations

Several limitations are associated with this indicator:

- The data that do exist are based primarily on sales information and use estimates. Gross sales data are not necessarily a reflection of fertilizer usage, nor do they convey any information about the efficiency of application of various nutrients.
- A variety of factors such as weather and crop type influence the amount of fertilizer used by farmers from year to year. A decrease in usage over time may be due to a reduced reliance on these chemicals or a change in crop rotation, weather, or other factors, and may not be permanent.
- These data do not necessarily reflect residential fertilizer use.

Data Source

The data source for this indicator is the *Agricultural Resources and Environmental Indicators Report,* U.S. Department of Agriculture, Economic Research Service, 2000. (See Appendix B, page B-21, for more information.)

3.2.4 What is the potential disposition of chemicals from land?

Indicators

Pesticide residues in food
Potential pesticide runoff from farm fields
Risk of nitrogen export
Risk of phosphorus export

Disposition describes the potential for chemicals and nutrients to move from their location of use or origin to a place in the environment where humans and other organisms can be exposed to them. People can be affected by these chemicals and nutrients when exposed to them through foods, drinking water supplies, or in the air they breathe. The environment can be affected when these chemicals accumulate on land or enter the water. A significant challenge lies in tracking the movement of pesticides and fertilizers in the environment and then correlating their existence in water or air to health or environmental effects. These chemicals often move through the environment and react in ways that are difficult to track and understand.

Pesticide contamination of ground water is a potential problem when leachable pesticides are applied to soils. Soil leaching potential can be determined by assigning rankings to organic matter, clay content, and acidity, which are the three main factors controlling pesticide leaching through soils (Hellkamp, et al., 1998). Pesticide-leaching potential is a measure of how tightly and quickly a pesticide binds to organic particles and is determined by the leaching potential of the pesticide itself, the pesticide's persistence, and the rate and method of application. Some analysis of the pesticide leaching risk based on these variables has been conducted in the mid-Atlantic region, showing that relatively little acreage has a high potential for leaching. Other variables should also be considered in assessing the risk of pesticide leaching including precipitation, antecedent soil moisture conditions, soil hydraulic conductivities and permeability, and water table depths.

Under ideal circumstances, crops would take up the vast majority of nutrients that are applied as fertilizers to soil, but many factors, including weather, overall plant health, and pests, affect the uptake ability of crops. When crops do not use all applied nutrients, residual concentrations of nutrients and other components of chemical fertilizers remain in the soil and can become concentrated in ground water and surface water. The USGS National Water Quality Assessment provides one measure of these chemical concentrations in waterbodies based on samples from 36 major river basins and aquifers (see Chapter 2, Purer Water). Calculating residual concentrations (known as the "residual balance") for agricultural areas provides an understanding of the potential risks fertilizer use poses to local environmental conditions. If the residual balance is positive, then excessive nutrients may exist and present an ecological risk. If it is negative, then plants are taking up not only the amount of nutrient added by the fertilizer but others already present in the soil and atmosphere. In this case, the soil might be depleted over time (Vesterby, 2003).

Four indicators are considered on the following pages, one that measures the actual presence of chemicals in food, and three that assess the potential for pesticides and nutrients to runoff the land.

Indicator: Pesticide residues in food - Category 1

An indication of the amount of pesticides that are detectable in the U.S. food supply provides information about the disposition of some chemicals. Food is one of the pathways through which people can be exposed to the effects of pesticides. USDA has maintained a Pesticide Data Program (PDP) since 1992 that collects data on pesticide residues on fruits, vegetables, grains, and in dairy products at terminal markets and warehouses. Thousands of samples have been analyzed for more than 100 pesticides and their metabolites on dozens of commodities. Samples are collected by USDA immediately prior to these commodities being shipped to grocery stores and supermarkets. They are then prepared in the laboratory as if for consumption (e.g., washed, peeled, cored, but not cooked) so that samples are more likely to reflect actual exposures. Pesticide residue levels are then measured.

What the Data Show

The Department of Agriculture's Pesticide Data Program (PDP) measures pesticide residue levels in fruits, vegetables, grains, and dairy products from across the country, sampling different commodities each year. In 2000, PDP collected and analyzed a total of 10,907 samples: 8,912 fruits and vegetables, 178 rice, 716 peanut butter, and 1,101 poultry tissue samples which originated from 38 States and 21 foreign countries. Approximately 80 percent of all samples were domestic, 19 percent were imported, Indicator Pesticide residues in food - Category 1 (continued)

and less than 1 percent were of unknown origin. Overall, approximately 42 percent of all samples contained no detectable residues, 22 percent contained 1 residue, and 35 percent contained more than 1 residue. Detectable residues are not inherently violations of regulatory tolerances. Residues exceeding the pesticide tolerance were detected in 0.2 percent of all composite samples. Residues with no tolerance level were found in 1.2 percent of all samples. These residues were detected at low concentrations and may be due to spray drift, crop rotations, or cross contamination at packing facilities. PDP reports these findings to the Food and Drug Administration.

Indicator Gaps and Limitations

Limitations for this indicator include the following:

- The PDP does not sample all commodities over all years, so some gaps in coverage exist. For example, a specific commodity might be sampled each year for a two or three year period and then not be sampled for two or more years before being re-sampled during a subsequent period. Differences in the percent of detections for any given class of pesticides might not be due to an increase (or decrease) in the predominance of detectable residues, but might simply reflect the changing nature and identity of the commodities selected for inclusion in any given time frame (given that each PDP "market basket" of goods differs to some extent over time).
- The PDP has the ability to detect pesticide residues at concentrations that are orders of magnitude lower than those determined to have human health effects. The simple presence of detectable pesticide residues in foods should not be considered indicative of a potential health concern (USDA, AMS, 2002).

Data Source

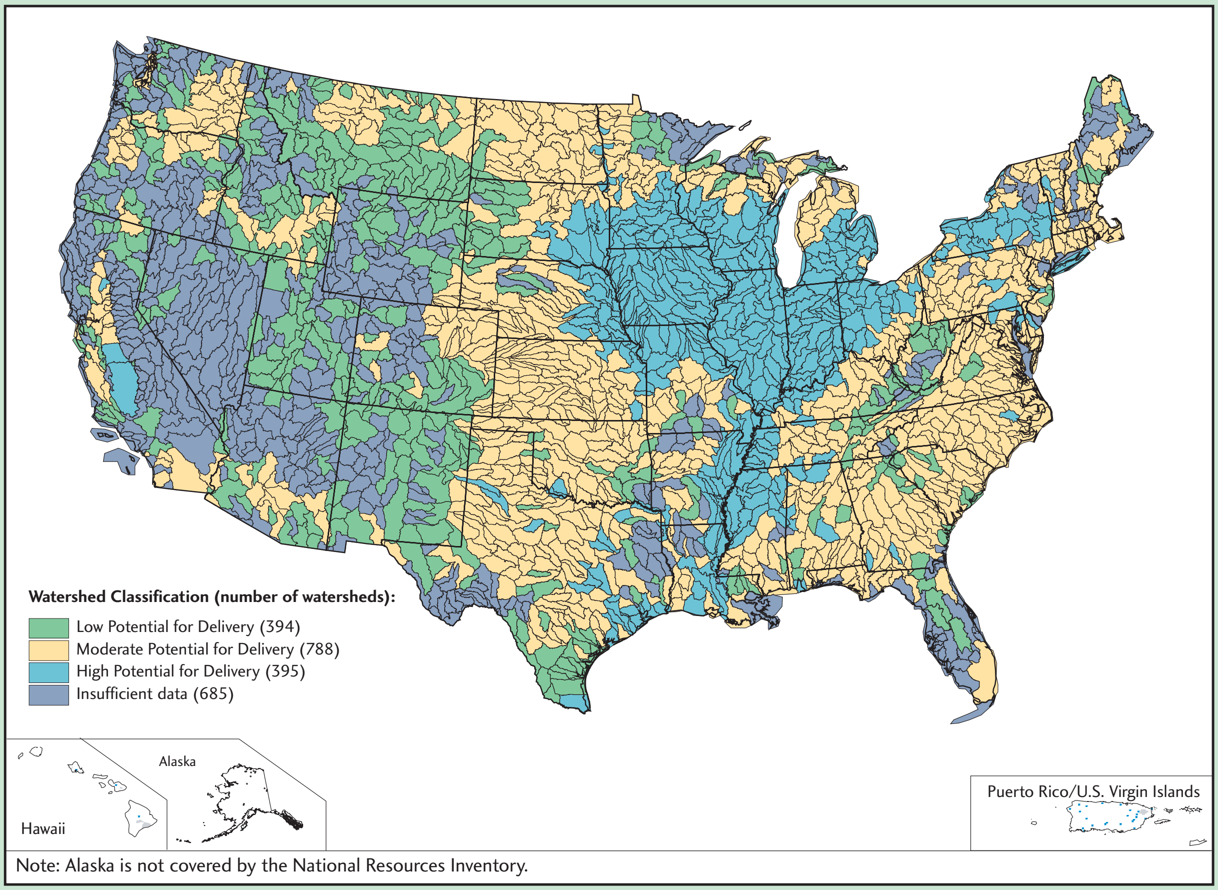
The data source for this indicator is the *Pesticide Data Program: Annual Summary Calendar Year 2000,* U.S. Department of Agriculture, Agricultural Marketing Service. (See Appendix B, page B-21, for more information.)

Indicator — Potential pesticide runoff from farm fields - Category 2

This indicator identifies the potential for movement of agricultural pesticides by surface water runoff in watersheds nationwide. The indicator represents potential loss at the edge of a field based on factors that are known to be important determinants of pesticide loss, including: 1) soil characteristics, 2) historical pesticide use, 3) chemical properties of the pesticides used, 4) annual rainfall and its relationship to runoff, and 5) major field crops grown using 1992 as a baseline. Watersheds with high scores (i.e., the "high potential for delivery" class) have a greater risk of pesticide contamination of surface water than do those with low scores (i.e., the "low potential for delivery" class). (See Section 3.1.6 for more on runoff categories.)

Calculations for watershed pesticide runoff potential are based on a National Pesticide Loss Database, that uses the chemical fate and transport model GLEAMS (Groundwater Loading Effects of Agricultural Management). GLEAMS is a model that estimates pesticide leaching and runoff losses using the following as inputs: soil properties, field characteristics (e.g., slope and slope length), management practices, pesticide properties, and climate. GLEAMS estimates were generated for 243 pesticides applied to 120 specific soils; the estimates are for 20 years of daily weather for each of 55 climate stations distributed throughout the U.S. (Knisel, 1993).

Exhibit 3-19: Potential pesticide runoff from farm fields, 1990-1995



Source: USDA, Natural Resources Conservation Service. *National Resources Inventory.* 1992; Gianessi, L.P., and J.E. Anderson. *Pesticide Use in US Crop Production: National Data Report.* February 1995; Goss, Don W. Pesticide Runoff Potential, 1990-1995. August 24, 1999. (September 2002; *http://www.epa.gov/iwi/1999sept/iv12a_usmap.html*).

Indicator | Potential pesticide runoff from farm fields - Category 2 (continued)

Chemical use for 13 different crops taken from the National Pesticide Use Database was estimated for 1990-1993 (Gianessi and Anderson, 1995). A total of 145 pesticides were included in the derivation of the pesticide runoff indicator (using the joint set of pesticides from the National Pesticide Use Database and the National Pesticide Loss Database for the 13 crops). Estimates of percent of acres treated and average application rates were imputed to the NRI sample points by crop and state. Each NRI sample point where corn was grown in Iowa, for example, included chemical use for 22 of the pesticides Gianessi and Anderson reported were used on corn in Iowa. The simulation assumed that each pesticide was applied at the average rate for the state. In reality, pesticide use varies widely from field to field. The simulation thus reflects general pesticide use patterns to provide an indication of where the potential for loss from farm fields is the greatest.

The total loss of pesticides from each representative field was estimated by 1) multiplying the estimate of percent loss per acre by the application rate to obtain the mass loss per acre for each pesticide, 2) calculating the number of acres treated for each pesticide by multiplying the estimate of percent acres treated by the number of acres associated with the sample point, 3) multiplying the number of acres treated by the mass loss per acre to obtain the mass loss for the representative field for each pesticide, and 4) summing the mass loss estimates for all the pesticides.

Watershed scores were determined by averaging the scores for the NRI sample points within each watershed. The average watershed score was determined by dividing the aggregate pesticide loss for the watershed by the number of acres of non-federal rural land in the watershed. Dividing by the acres of non-federal rural land provides a watershed level perspective of the significance of pesticide loss.

What the Data Show

Exhibit 3-19 shows the distribution of watersheds and the potential for pesticide runoff nationwide. The highest potential for agricultural pesticide runoff is concentrated in the central U.S., predominately associated with the upper and lower Mississippi River Valley and the Ohio River Valley.

Indicator Gaps and Limitations

The following limitations are associated with this indicator:

- The indicator estimates only the potential for pesticides to run off farm fields. It does not estimate actual pesticide loss. Research has shown that pesticide loss from farmlands can be substantially reduced by management practices that enhance the water-holding capacity and organic content of the soil, reducing water runoff. Where these practices are being used, the potential loss measured by this indicator will be overestimated because the practices are not considered in the analysis.
- The indicator does not include croplands used for growing fruits, nuts, and vegetables. Thus, watersheds with large acreage of these crops will have a greater risk of water quality contamination than shown by this indicator.
- For each field, pesticide usage was assumed as an average for the state, when actual use varies widely.
- This indicator does not address pesticide usage in non-agricultural areas.

Data Sources

The data sources for this indicator are the *Summary Report: 1997 National Resources Inventory (Revised December 2000)*, U.S. Department of Agriculture, Natural Resources Conservation Service, and the National Pesticide Use Database, National Center for Food and Agricultural Policy, 1995. (See Appendix B, page B-21, for more information.)

Indicator Risk of nitrogen export - Category 2

Predictive risk models show higher nutrient concentrations in watersheds dominated by agricultural and urban and suburban land uses. Watersheds with mixed uses tend to have forested lands that reduce concentrations of nutrients. Various field-based studies show a strong relationship between land cover and the amount of nutrients exported from a watershed (e.g., measured in the stream at the watershed outlet) (Beaulac and Reckhow, 1982). Exports are typically measured as mass per unit area per unit time (e.g., lbs/acre/year). Nitrogen exports tend to increase as agriculture and urban and suburban uses replace forest land. Several additional factors affect the actual amount exported, however, such as cropping management practices, the timing of rainfall versus cropping stage, density of impervious surfaces, and soil types.

The risk classes described by this indicator are based solely on proportions of agriculture, forest, and urban and suburban land within a watershed derived from the NLCD. Nutrient export data compiled from watersheds with homogenous land cover were used in a Monte Carlo approach to simulate loads of nitrogen for watersheds with mixed land cover. The model can be used to estimate annual load for any point in the distribution or for risk of exceeding user-defined thresholds. When used to estimate risk, the model conceptually incorporates factors other than land cover as mentioned above.

What the Data Show

Exhibit 3-20 shows the risk of nitrogen export. Risk is expressed as the number of times per 10,000 trials the nitrogen export exceeded a threshold of 6.5 lbs/acre/year. The 6.5 threshold was chosen because it represents the maximum value observed for watersheds that were entirely forest. A risk value of 0.5 indicates a 1 out of 2 chance that a particular watershed would exceed the risk threshold because of its mix of land cover (e.g., forest, agriculture, urban/suburban). The watersheds in Exhibit 3-20 are categorized into five classes based on risk. About 46 percent of the watersheds are in the lowest risk class and 15 percent in the highest. The lowest risk watersheds make up most of the western U.S., northern New England, northern Great Lakes, and southern Appalachians. The highest risk classes are concentrated in the midwestern grain belt. The eastern U.S. shows a mottling of high and low risk classes among adjacent watersheds.

Indicator Gaps and Limitations

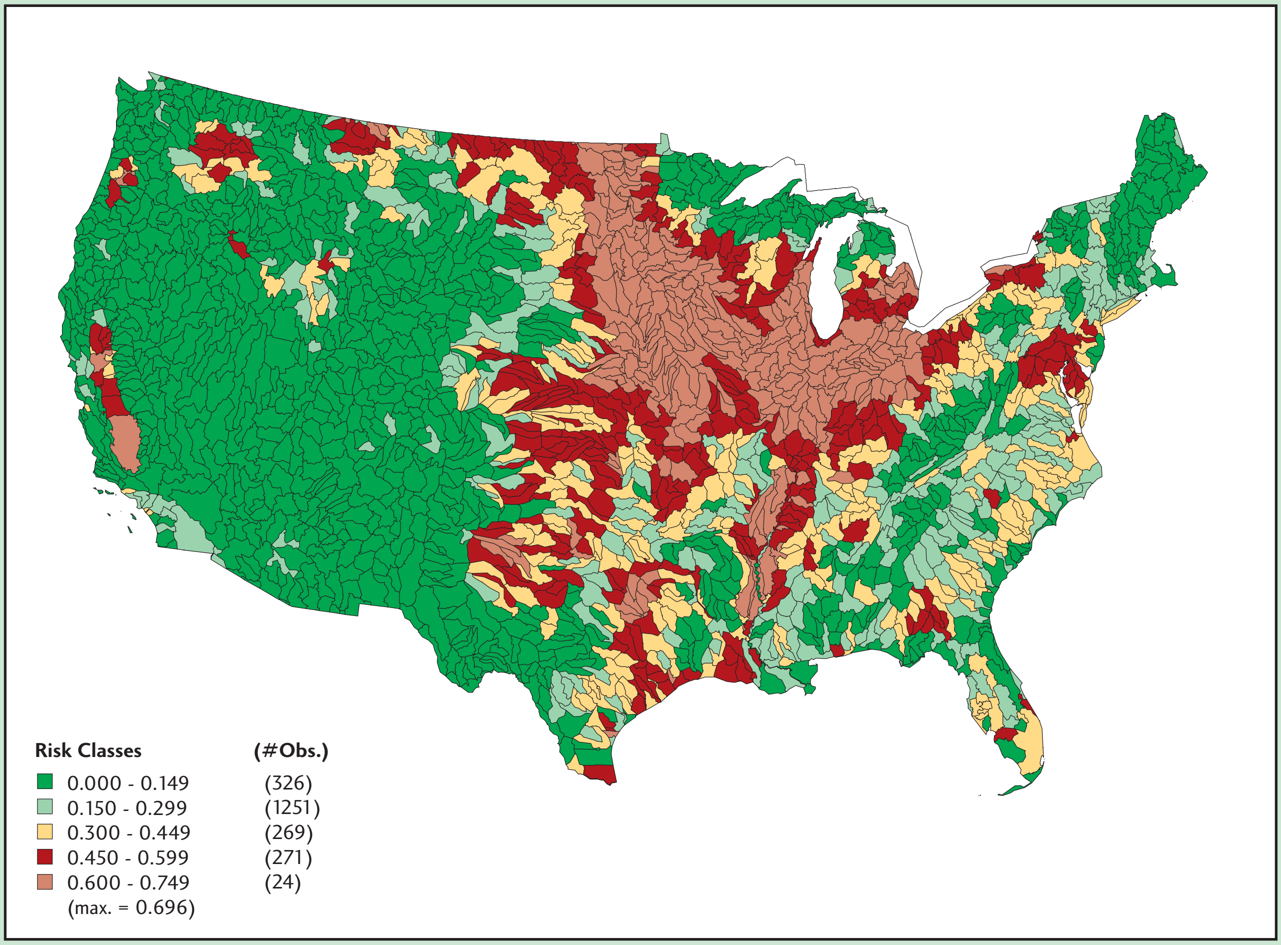
The potential risk of nitrogen runoff calculated from the NLCD data relies on various classifications and models that have inaccuracies that might affect results. To nationally monitor all watershed variables that affect nutrient export is impossible. Therefore, the data for this indicator are based on statistical simulation and the well-documented relationship between land cover and nutrient export to estimate the risk (or likelihood) of export exceeding a certain threshold. The accuracy of the model is affected by the accuracy of the classification of the cover types—forest, agriculture, and urban/suburban—which range from 80 percent to 90 percent in most cases. The accuracy also is affected by lack of model input for other land cover classes that can occur within watersheds, particularly in the western U.S. Model performance has been evaluated in the mid-Atlantic region, and modeled results generally agree with observed values. In the western U.S., shrubland and grassland cover share dominance with forest and agriculture. For national application of the model, shrubland and grassland classes were treated as forest because these land-cover classes, like forest, lack strong anthropogenic inputs of nitrogen. Further research to refine the empirical models for shrubland and grassland cover classes would be useful.

Data Sources

The data source for this indicator is the National Land Cover Data, Multi-Resolution Land Characteristics Consortium, 1992. (See Appendix B, page B-22, for more information.)

Indicator Risk of nitrogen export - Category 2 (continued)

Exhibit 3-20: Estimates of risk of nitrogen export by watershed, 1992



Source: Wickham, J.D. et al., *Land Cover as a Framework for Assessing Risk of Water Pollution.* 2000.

Indicator Risk of phosphorus export - Category 2

Like nitrogen export, the same strong relationship exists between land cover and phosphorus export. Risk is expressed as the number of times out of 10,000 trials that the phosphorus export threshold of 0.74 lbs/acre/year was exceeded. The 0.74 threshold was chosen because it represents the maximum value observed for watersheds that were entirely forest. The model uses an identical approach to that just described in the "risk of nitrogen export" indicator.

What the Data Show

Exhibit 3-21 shows potential for phosphorus export at greater than 0.74 pounds per acre per year. About 74 percent of the watersheds are in the two lowest risk classes. These make up most of the western U.S., as well as the eastern seaboard and the Appalachians. Only 1 percent of the watersheds are in the highest risk classes, and these are scattered throughout the midwestern grain belt, but also in many of the nation's major urban/suburban

Indicator Risk of phosphorus export - Category 2 (continued)

areas. Many major urban/suburban areas exist at the intersection of two watersheds, and the "urban" influence, which would make the phosphorus risk higher, is spread over multiple watersheds. This partially explains why some urban/suburban areas show lower risk than others. Identification of higher phosphorus export risk in urban/suburban areas differs somewhat from the spatial pattern for nitrogen export risk, because the empirical data suggest that urban/suburban areas present higher risk of phosphorus export than nitrogen export.

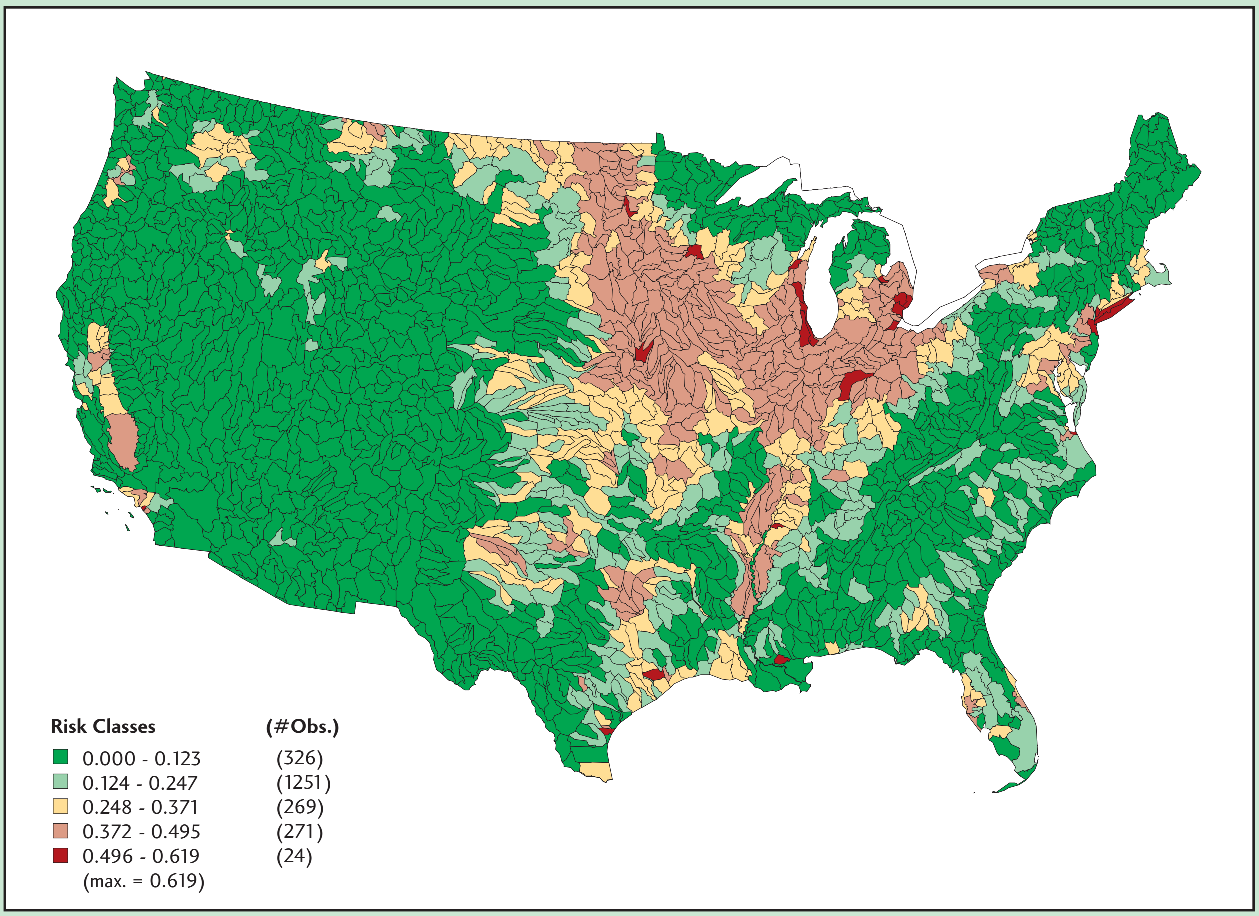
Indicator Gaps and Limitations

The potential risk of phosphorus export is based on the aggregate classes of forest, urban/suburban, and agriculture from the NLCD. Accuracy of these classes ranges from 80 to 90 percent in most cases. Model performance has been evaluated in the mid-Atlantic region, and modeled results generally agree with observed values. In the western U.S., shrubland and grassland cover share dominance with forest and agriculture. For national application of the model, shrubland and grassland classes were treated as forest, because these land-cover classes, like forest, lack strong anthropogenic inputs of phosphorus. Further research to refine the empirical models for shrubland and grassland land-cover classes would be useful.

Data Source

The data source for this indicator is the National Land Cover Data, Multi-Resolution Land Characteristics Consortium, 1992. (See Appendix B, page B-22, for more information.)

Exhibit 3-21: Estimates of risk of phosphorus export by watershed, 1992



Source: Wickham, J.D. et al., *Land Cover as a Framework for Assessing Risk of Water Pollution.* 2000.

3.2.5 What human health effects are associated with pesticides, fertilizers, and toxic substances?

Many pesticides pose some risk to humans and the environment because they are designed to kill or otherwise adversely affect living organisms. The degree to which individuals and populations are exposed to pesticides varies greatly by geographic location and demographics. Children may be more susceptible than adults to the effects of chemicals, including pesticides. Certain populations may be more at risk than others, depending, for example, on sources of drinking water or direct exposure to pesticide application.

Various pesticide surveillance systems exist that collect information on pesticide-related injury and illness, but data are limited. One example, the Toxic Exposure Surveillance System (TESS), contains information from poison control centers around the country that report occurrences of pesticide-related injury and illness.

Other data collected from poison control centers showed that in 2000, more than 100,000 people were sufficiently concerned about exposure to various types of pesticides to call their local Poison Control Center.

The TRI database tracks toxic chemicals because of the risks that these chemicals pose to human health and ecological condition. Studies have made accurate associations between isolated chemicals and their specific health effects. For example, the pesticide atrazine has been shown to have developmental and reproductive effects in animals and fish, depending on the level of exposure (EPA, OPP, 2002). PBT chemicals such as mercury and lead can cause acute or chronic health problems, even when people are exposed to small quantities of the chemicals (See box "Persistant Bioaccumulative Toxic Chemicals") (EPA, October 1999). Though these single chemical assessments are useful, a greater challenge lies in correlating the existence of chemicals that interact in the environment to the health effects observed in a given population.

Fertilizers are often applied in greater quantities than crops can absorb and end up in surface or ground water. Although fertilizers may not be inherently harmful, they can be linked to human health problems when excess nutrients cause algal blooms and eutrophication in waterbodies. Drinking ground water contaminated with runoff from some fertilizers can have severe or even fatal health effects, especially in infants and children (e.g., blue baby syndrome) (Amdur, et al, 1996).

Another emerging issue is the use of recycled industrial waste in fertilizer. Depending on the material and how it is processed, the presence of heavy metals such as lead or cadmium in fertilizers produced with recycled waste can introduce contaminants to the soil and increase the health risks associated with fertilizer use. Many states have begun to test and require labeling for fertilizers containing metals and hazardous waste.

No specific indicators have been identified at this time. There is additional discussion of human health effects of chemical use in Chapter 4, Human Health.

Persistent Bioaccumulative Toxic Chemicals

Human exposure to PBT chemicals increases over time because these chemicals persist and bioaccumulate in the environment. Therefore, even small quantities of these chemicals are of concern. In 1999, EPA lowered the TRI reporting threshold for 13 chemicals called persistent bioaccumulative toxic chemicals (PBTs), including dioxins, mercury, lead, and polychlorinated biphenyls (PCBs). Of the total 38 billion pounds of managed toxic chemicals in 2000, PBTs comprised approximately 72 million pounds. Of the total 7.10 billion pounds of toxic chemicals released to the environment, PBTs accounted for 12.1 million (less than 1 percent). The specific types of PBTs that comprised the 12.1 million pounds were polycyclic aromatic compounds (45 percent), mercury and mercury compounds (36 percent), PCBs (12 percent), pesticides (0.7 percent), and other PBTs (7 percent)(EPA, OEI, 2002).

3.2.6 What ecological effects are associated with pesticides, fertilizers, and toxic substances?

Nitrogen runoff from farmlands and animal feeding operations can contribute to eutrophication of downstream waterbodies and sometimes impair the use of water for drinking water purposes. Nutrient enrichment (nitrogen and phosphorus) is one of the leading causes of water quality impairment in the nation's rivers, lakes, and estuaries. EPA reported to Congress in 1996 that 40 percent of rivers in the U.S. were impaired due to nutrient enrichment; 51 percent of the surveyed lakes and 57 percent of the surveyed estuaries were similarly adversely affected (EPA, OW, December 1997). Nutrients have also been implicated in identification of the large hypoxic zone in the Gulf of Mexico, hypoxia observed in several East Coast states, and harmful algal bloom-induced fish kills and human health problems in the coastal waters of several East Coast and Gulf states .

Just as the sources of nitrogen in watersheds vary, so do the effects of exported nitrogen. While high levels of nitrogen might not affect the watersheds from which the nutrient is exported, exports can influence the condition of coastal estuaries and lakes. The effects vary with such factors as water-column mixing, sunlight, temperature, and the availability of other nutrients.

No specific indicators have been identified at this time. Effects of chemical use on ecological condition are discussed more extensively in Chapter 2, Purer Water; and Chapter 5, Ecological Condition.